ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN

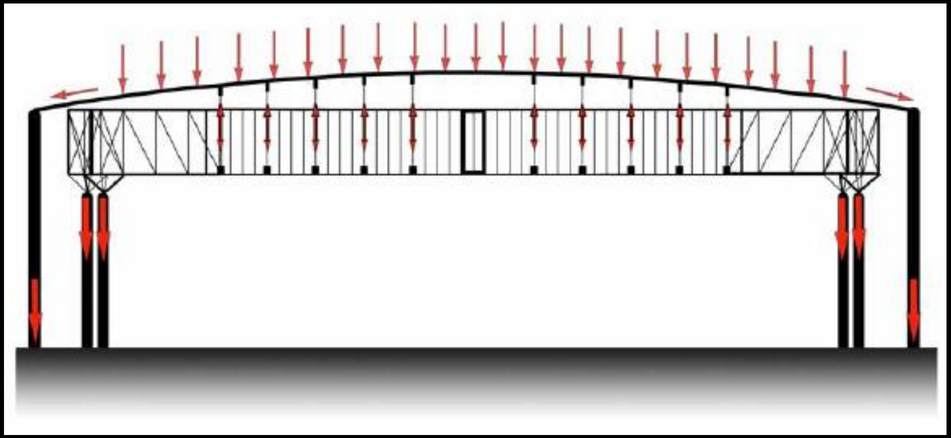
ARCH 331

DR. ANNE NICHOLS

FALL 2013

reed.tamu.edu

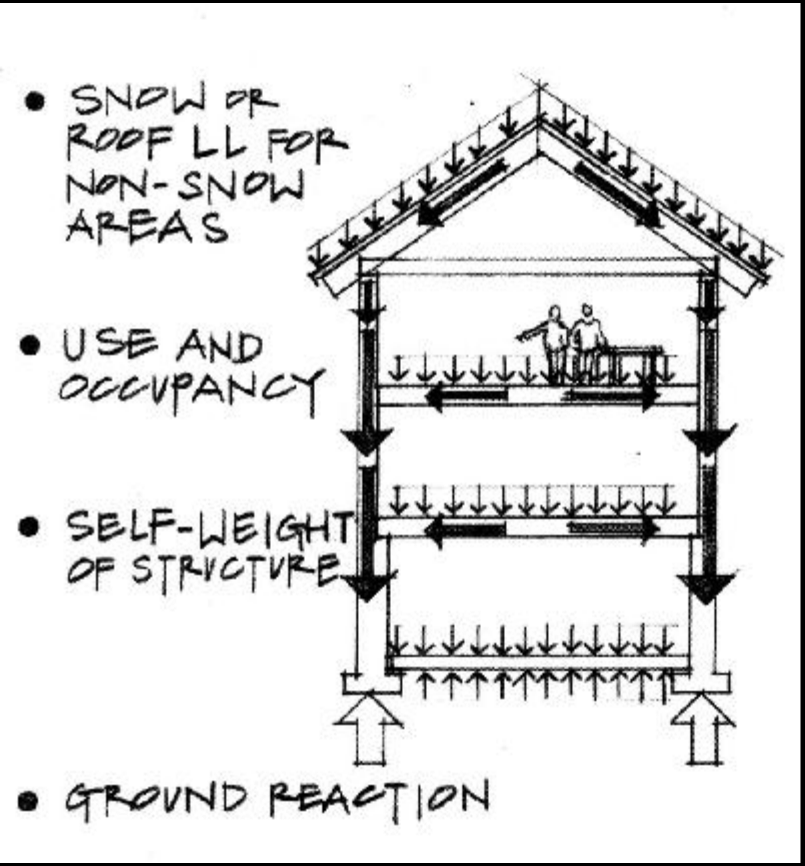
lecture
fourteen



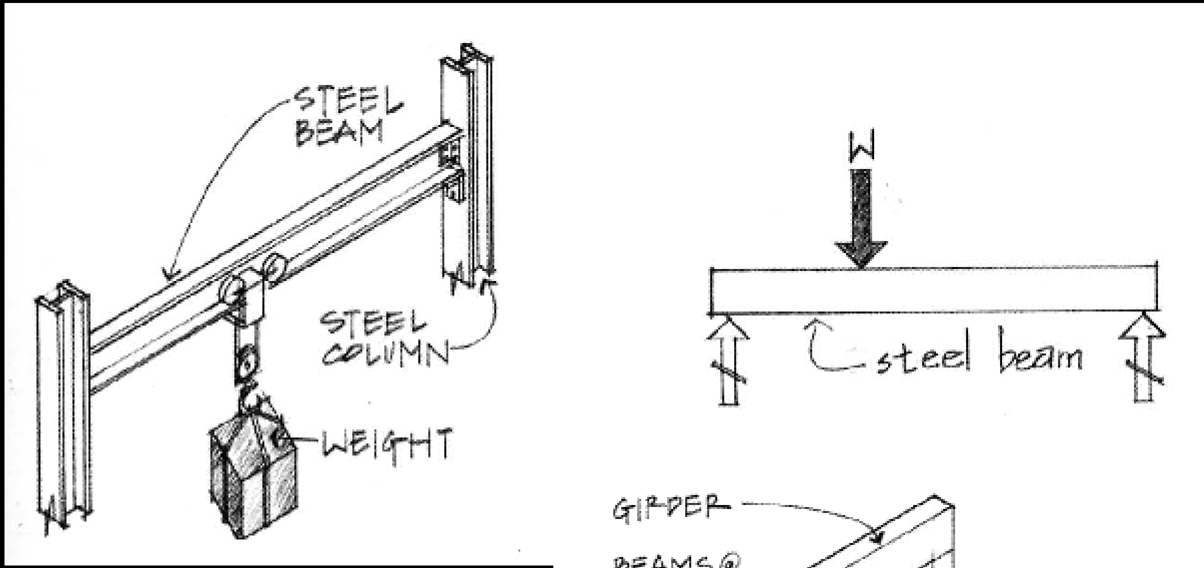
system assemblies & load tracing

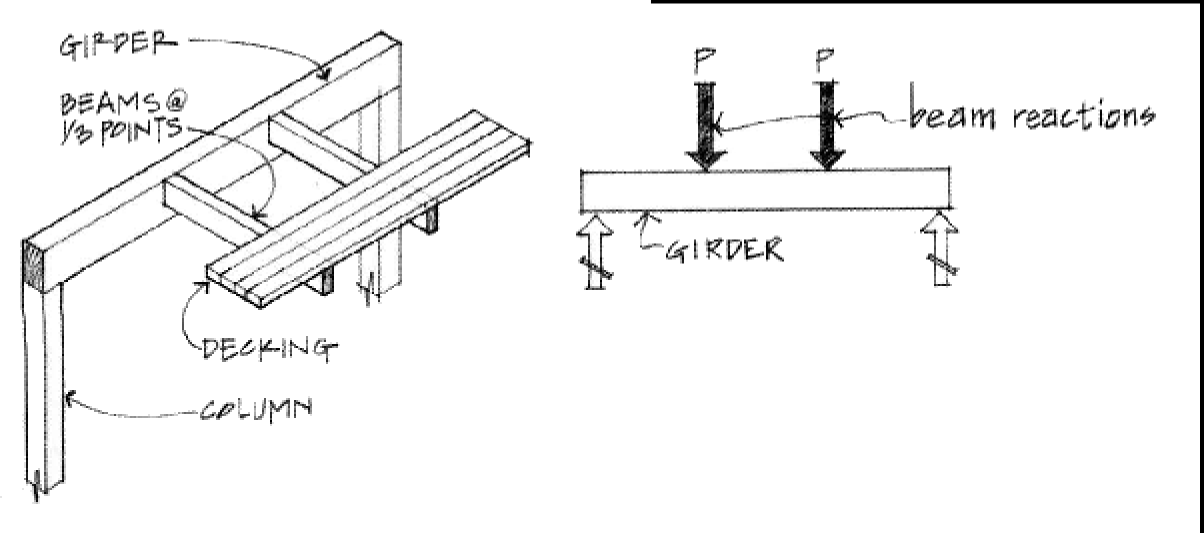
Structural Loads

- *gravity acts on mass (F=m*g)*
- *force of mass*
  - *acts at a point*
    - *ie. joist on beam*
  - *acts along a "line"*
    - *ie. floor on a beam*
  - *acts over an area*
    - *ie. people, books, snow on roof or floor*

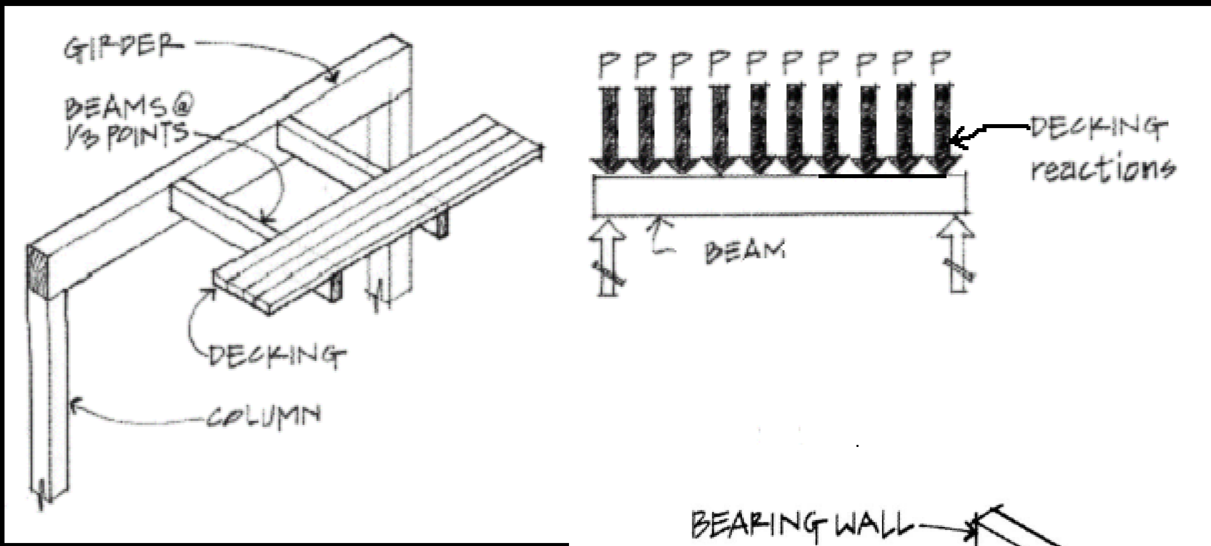


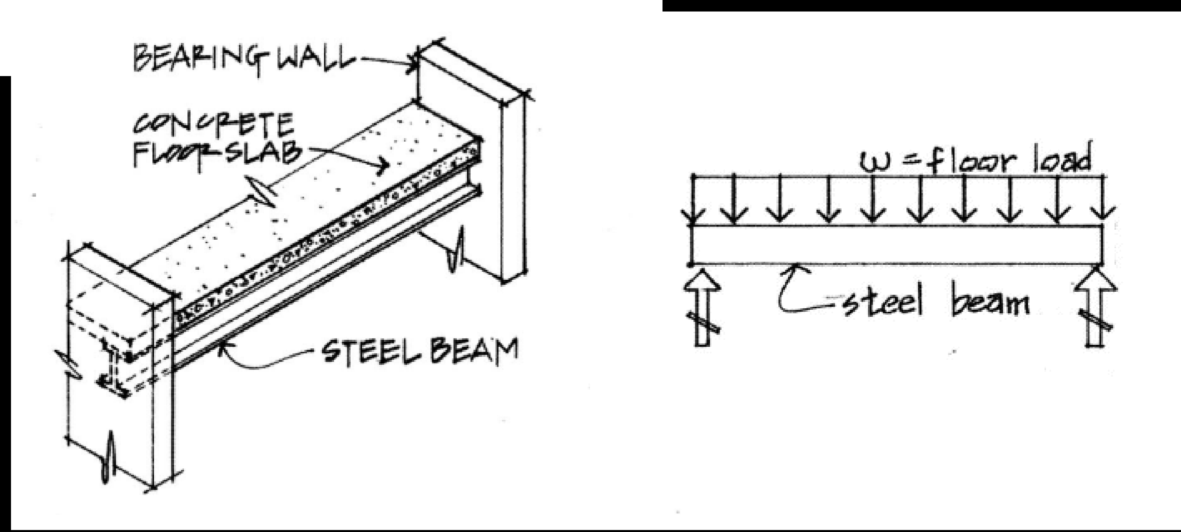
Concentrated Loads





Distributed Loads

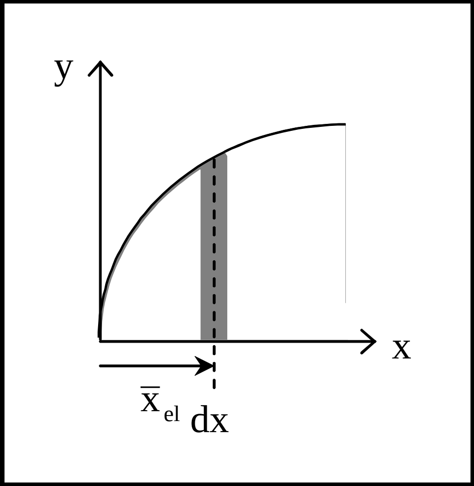


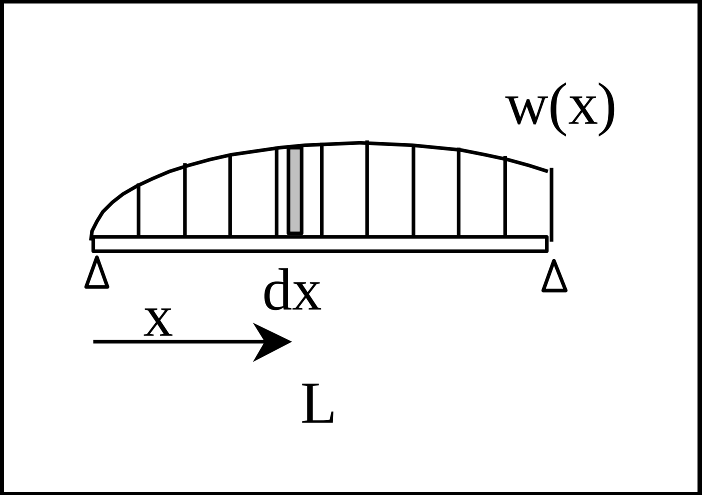


Equivalent Force Systems

- *replace forces by resultant*
- *place resultant where M = 0*
- *using calculus and area centroids*

$$W = \int_0^L w\,dx = \int dA_{loading} = A_{loading}$$

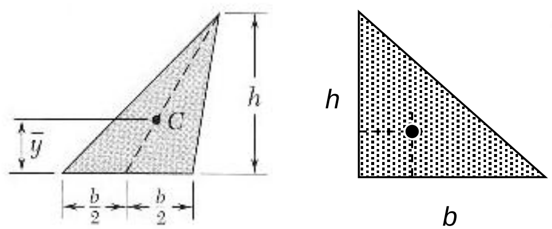
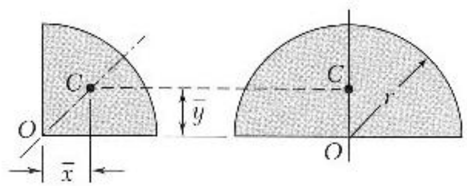
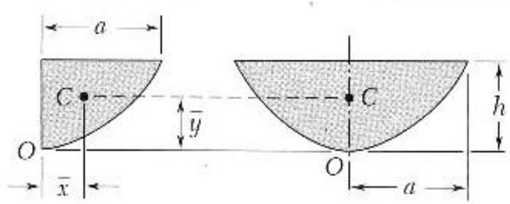




Area Centroids

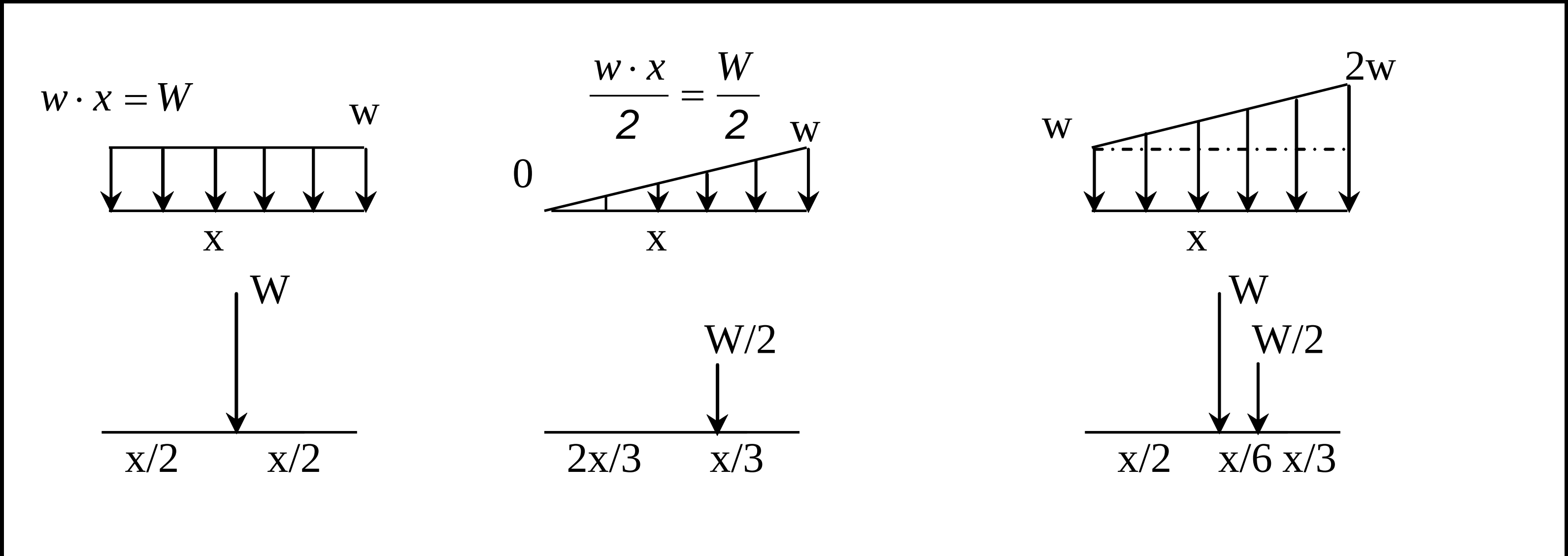
- *Table 7.1 – pg. 242*

Centroids of Common Shapes of Areas and Lines

Shape		$\bar{x}$	$\bar{y}$
Triangular area		$\frac{b}{3}$ *right triangle only*	$\frac{h}{3}$
Quarter-circular area		$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$
Semicircular area		0	$\frac{4r}{3\pi}$
Semiparabolic area		$\frac{3a}{8}$	$\frac{3h}{5}$
Parabolic area		0	$\frac{3h}{5}$

Equivalent Load Areas

- *area is width x "height" of load*
- *w is load per unit length*
- *W is total load*



Distributed Area Loads

- *w is <u>also</u> load per unit area*

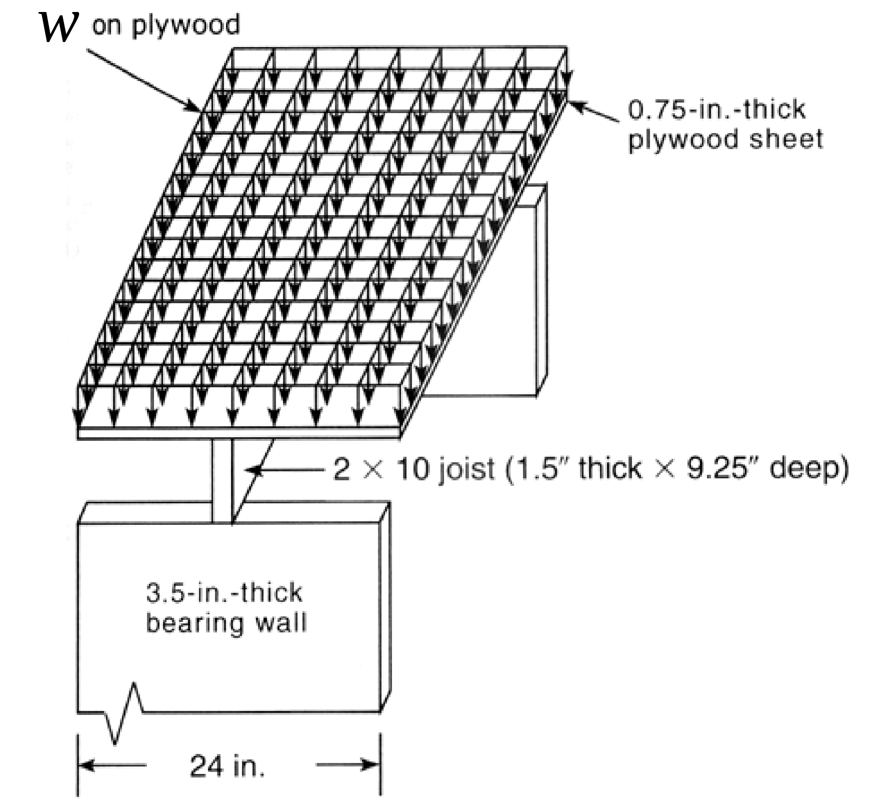
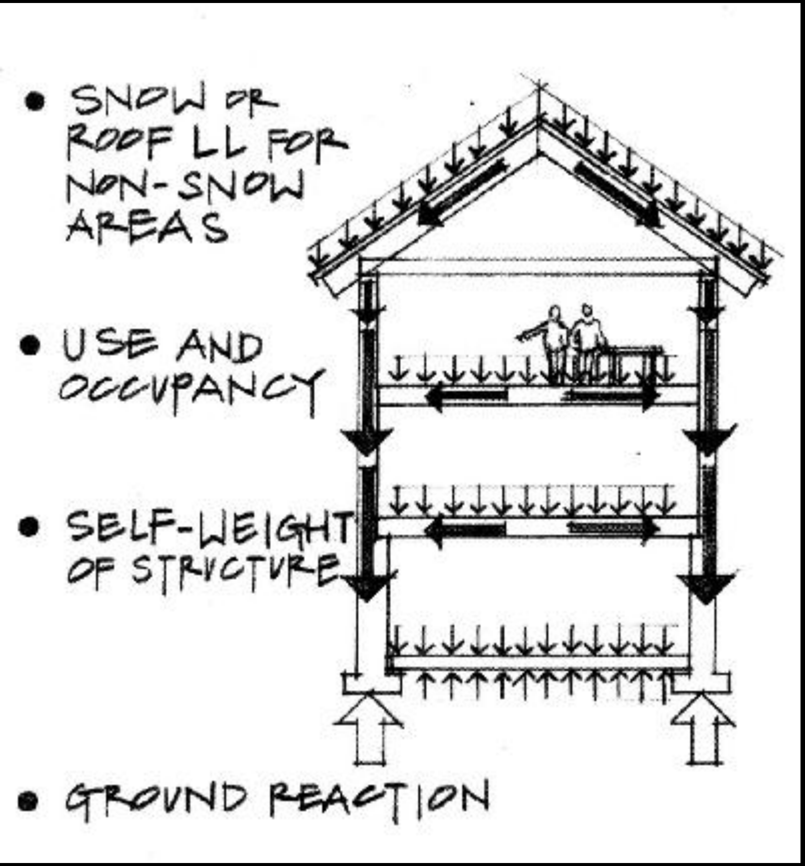


Figure 2.7 Area-distributed load (pressure) on floor decking.

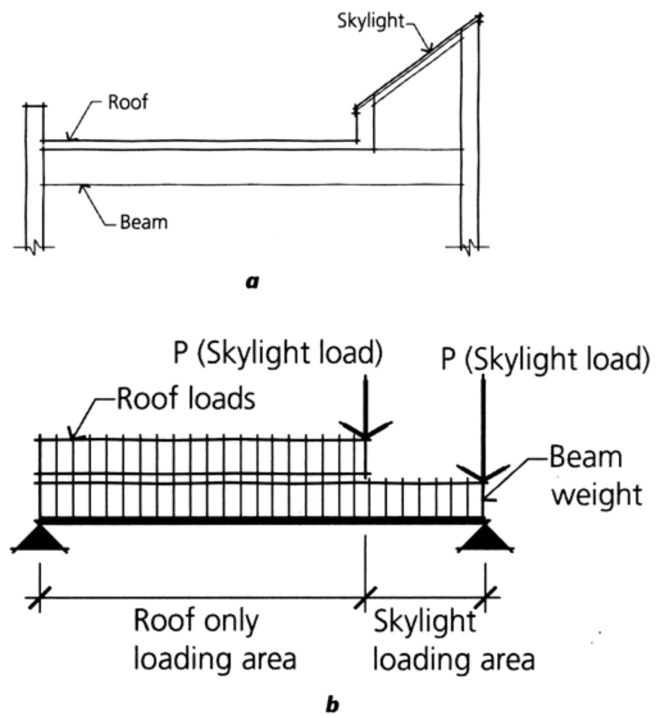
Load Tracing

- *how loads are transferred*
  - *usually starts at top*
  - *distributed by supports as <u>actions</u>*
  - *distributed by <u>tributary areas</u>*



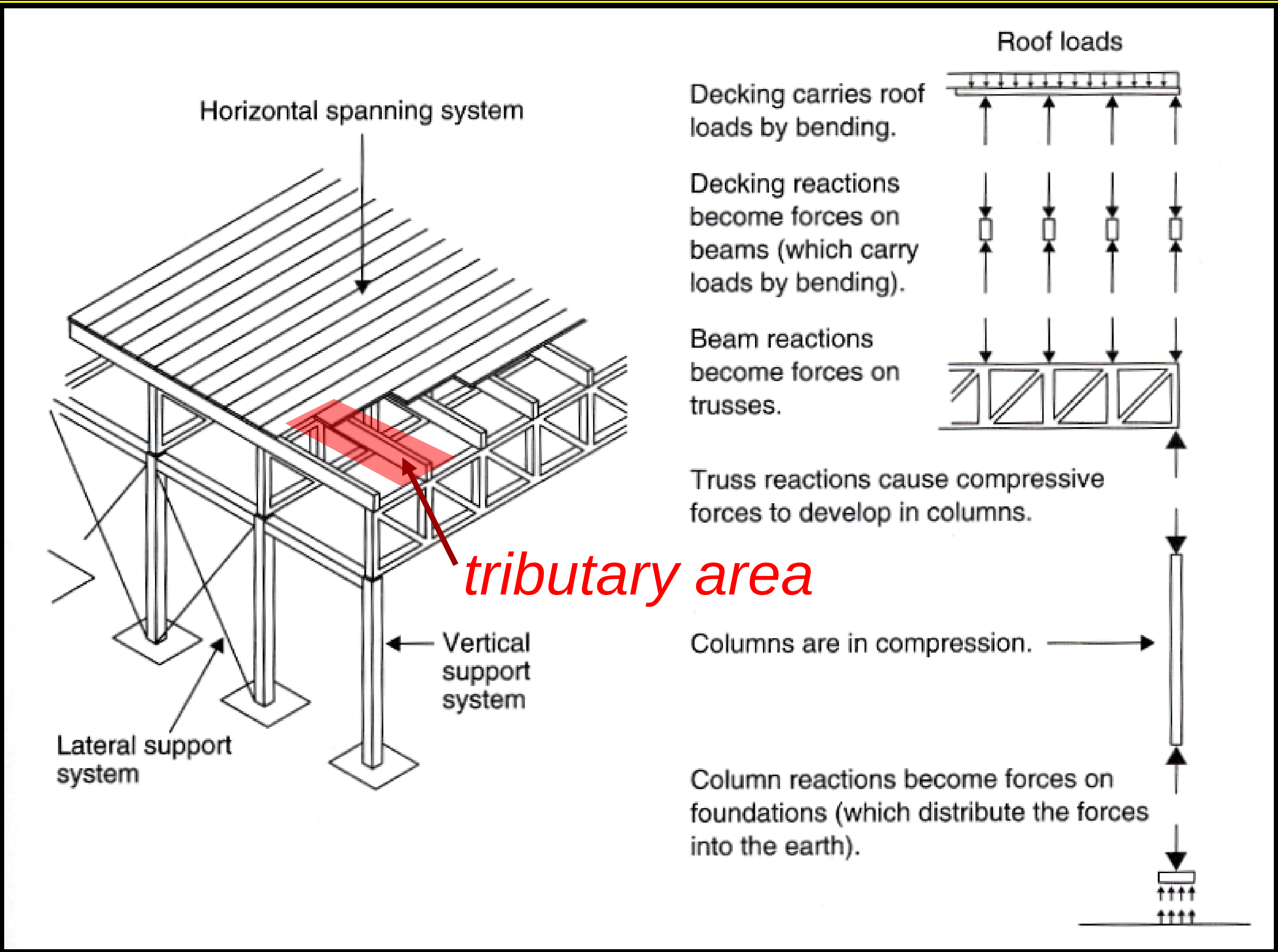
Load Tracing

- *areas see distributed area load*
- *beams or trusses see distributed line loads*
- *"collectors" see forces*
  - *columns*
  - *supports*



Figs. 1.1a, 1.1b Structural loading diagram of an architectural condition

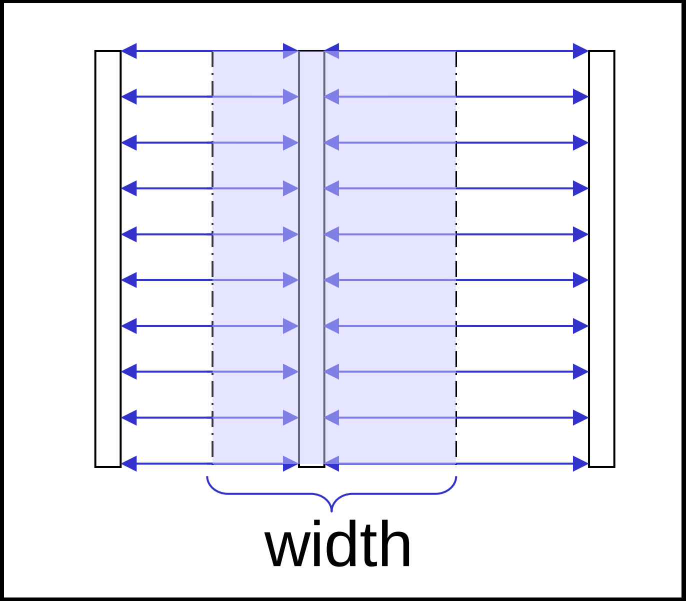
Load Tracing



Load Tracing

- *tributary load*
  - *think of water flow*
  - *“concentrates” load of area into center*

$$w = \left(\frac{load}{area}\right) \times (tributary\ width)$$



Load Tracing

www.columbia.edu

Patcenter
Rogers 1986

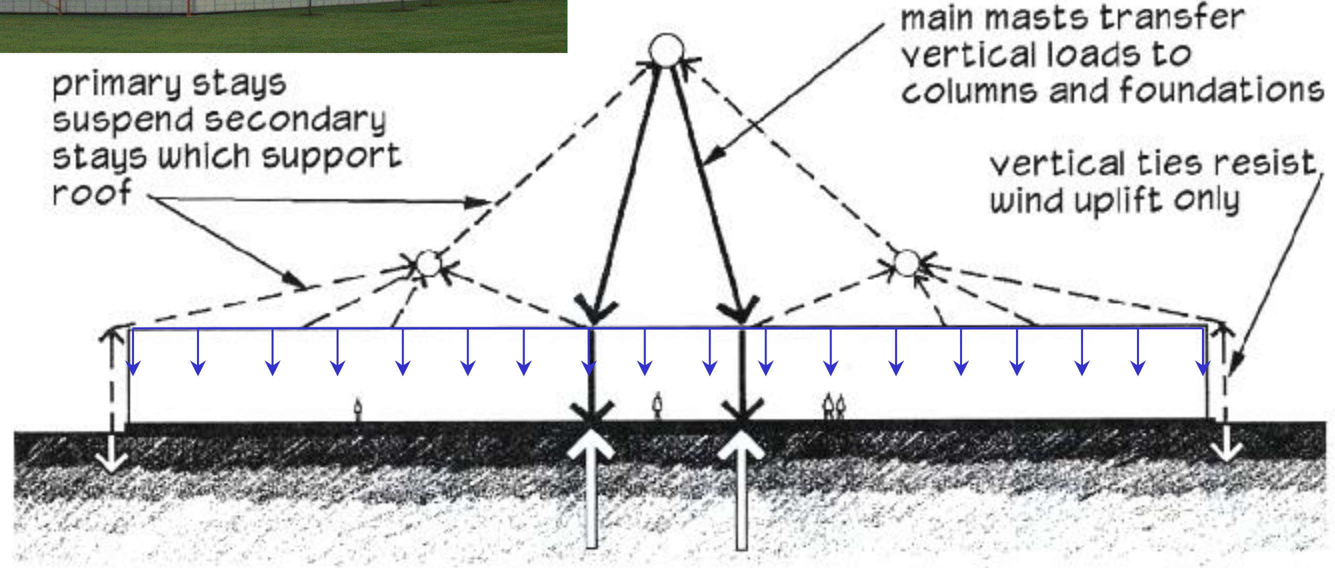


Figure 3.5: Patcenter, load path diagram.

Load Tracing

http://en.structurae.de

Alamillo Bridge
Calatrava 1992

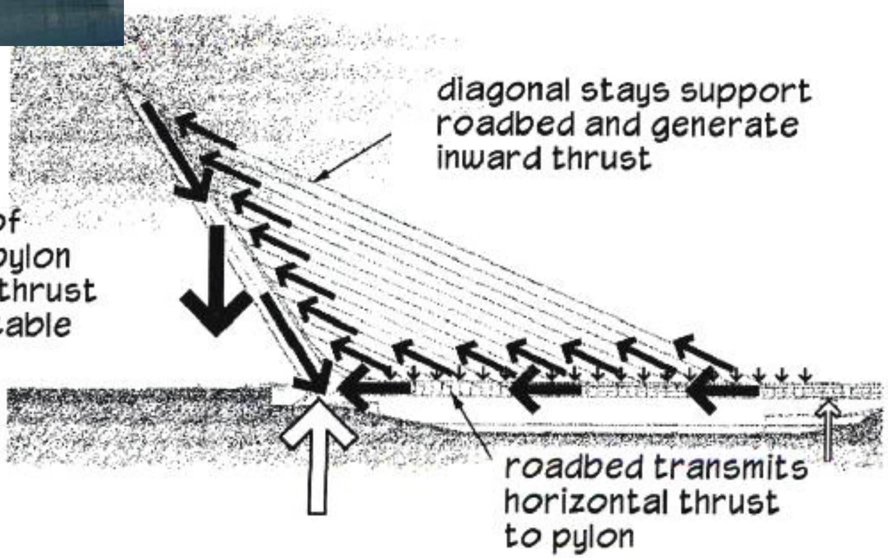
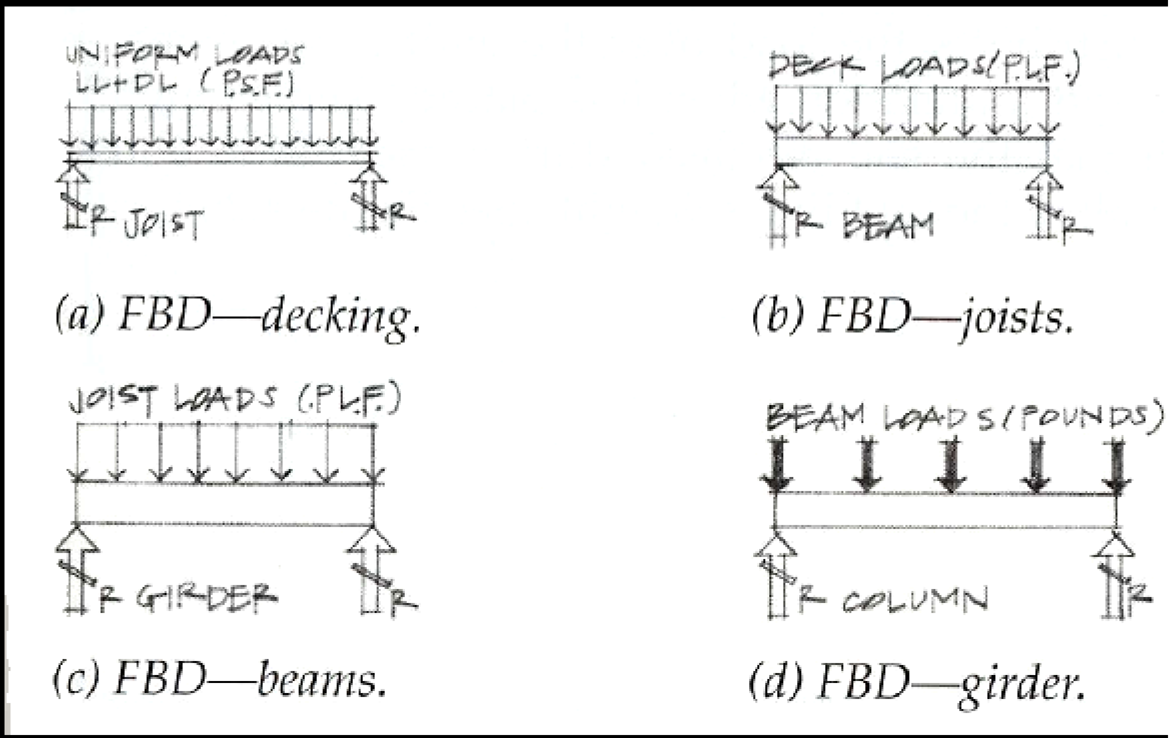


Figure 3.12: Alamillo bridge, load path diagram.

Load Paths

- *floors and framing*

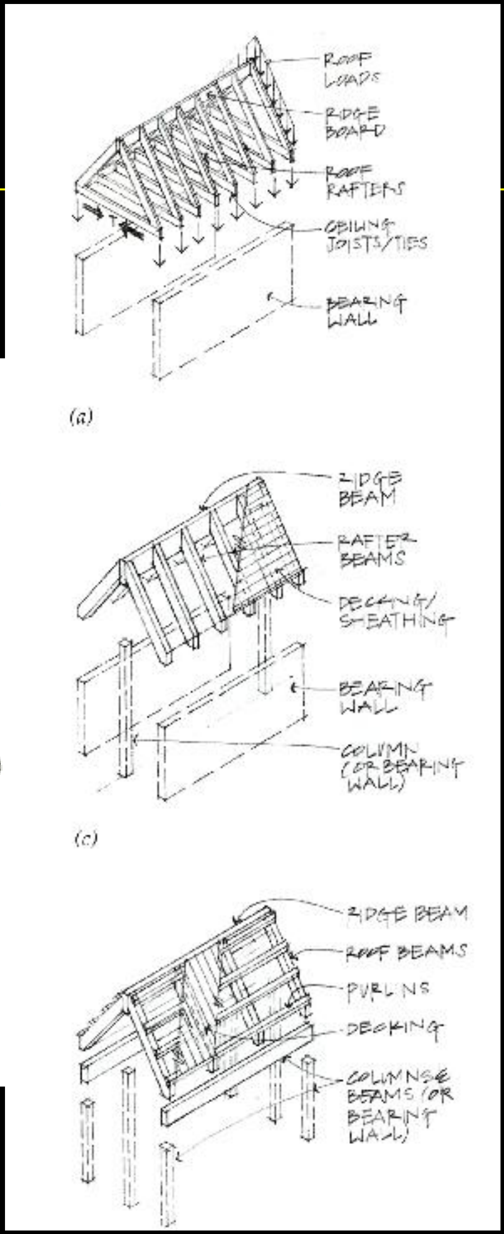


(a) FBD—decking.

(b) FBD—joists.

(c) FBD—beams.

(d) FBD—girder.



Load Paths

- *wall systems*

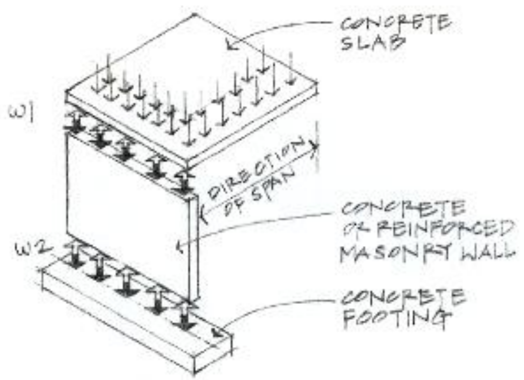


Figure 4.12 Uniform wall load from a slab.

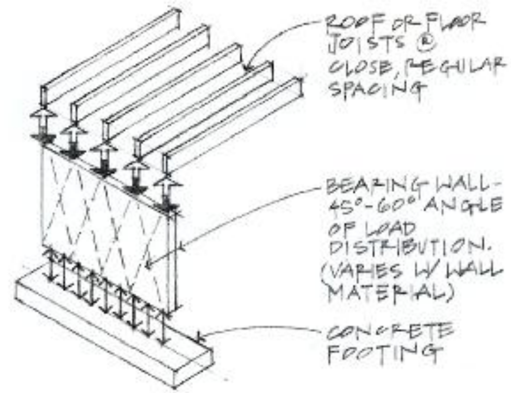


Figure 4.13 Uniform wall load from rafters and joists.

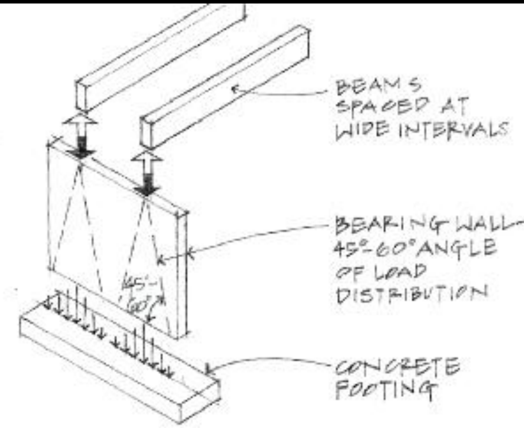


Figure 4.14 Concentrated loads from widely spaced beams.

Load Paths

- *openings & pilasters*

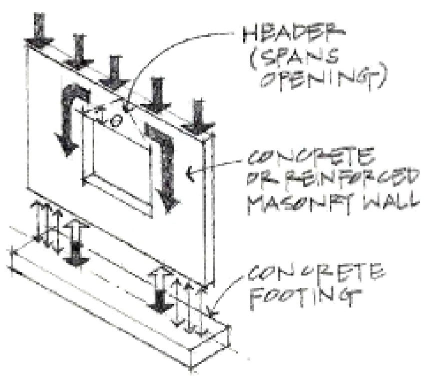


Figure 4.15 Arching over wall openings.

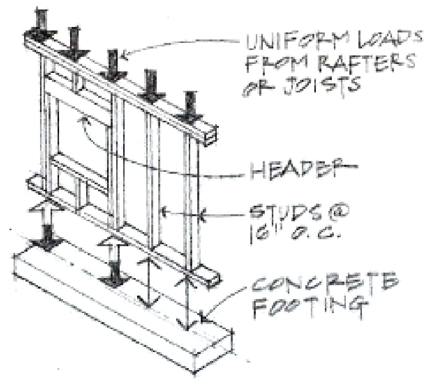


Figure 4.16 Stud wall with a window opening.

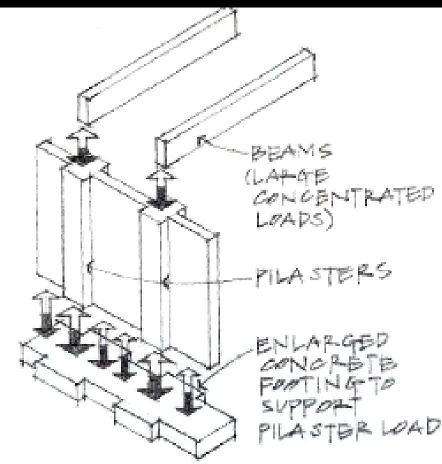


Figure 4.17 Pilasters supporting concentrated beam loads.

Load Paths

- *foundations*

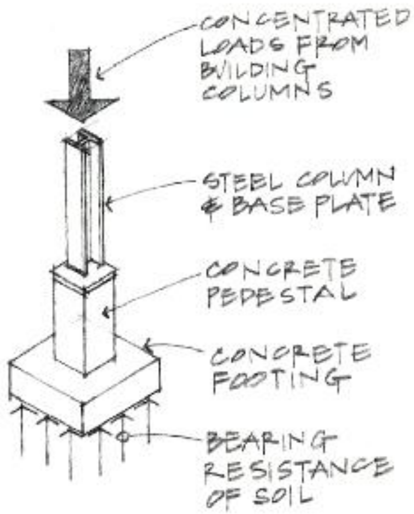


Figure 4.24 Spread footing.

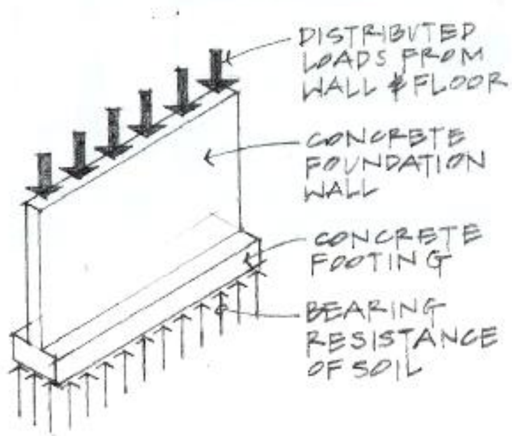


Figure 4.25 Wall footing.

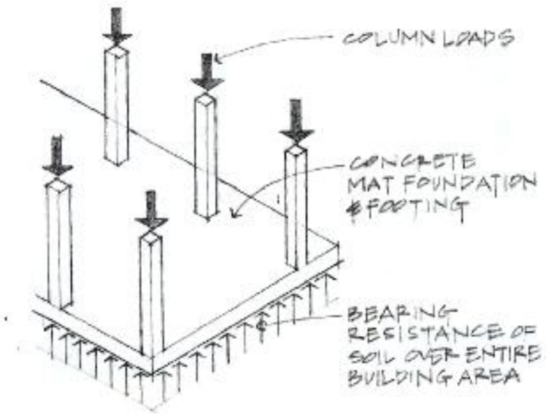


Figure 4.26 Mat or raft foundation.

Load Paths

- *deep foundations*

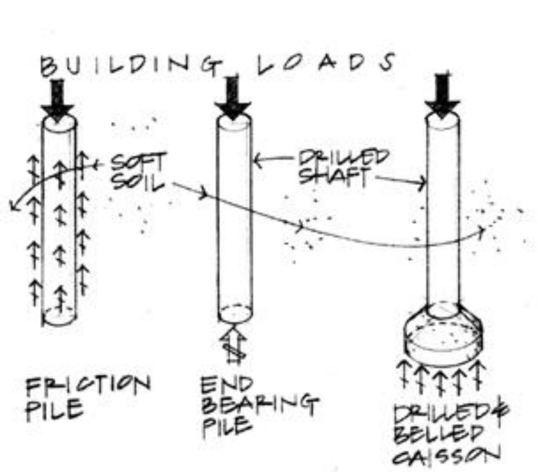


Figure 4.27 Pile foundations.

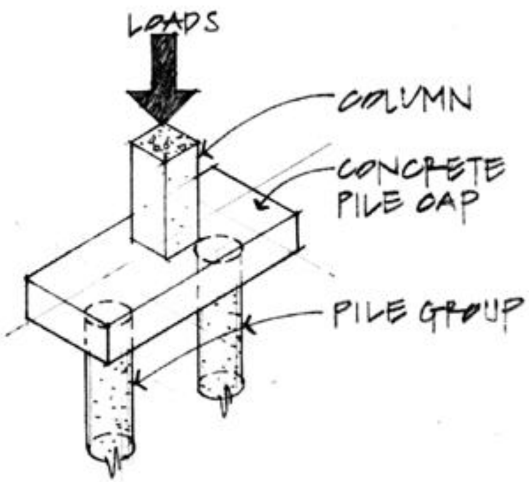


Figure 4.28 Pile cap on one pile group.

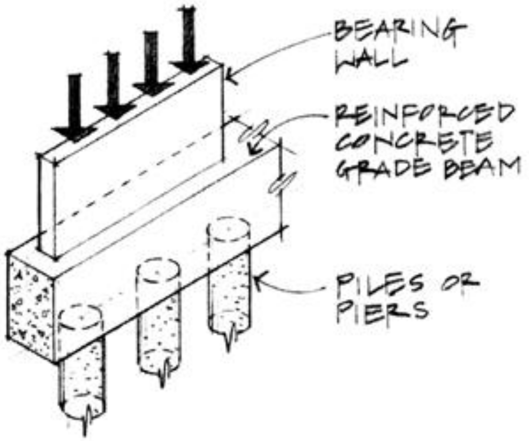
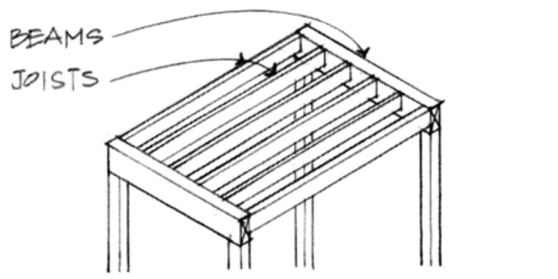


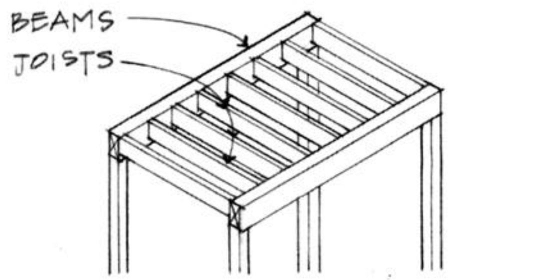
Figure 4.29 Grade beam supporting a bearing wall.

Spans

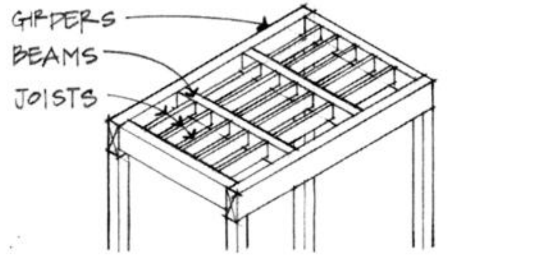
- *direction*
- *depth*



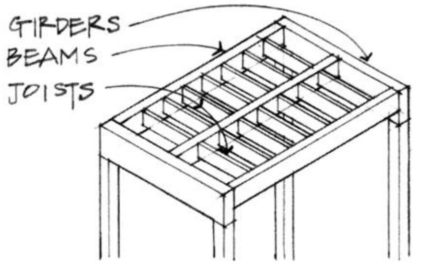
(a) Long, lightly loaded joists bearing on shorter beams create a more uniform structural depth. Space can be conserved if the joists and beams are flush framed.



(b) Short joists loading relatively long beams yield shallow joists and deep beams. The individual structural bays are more clearly expressed.



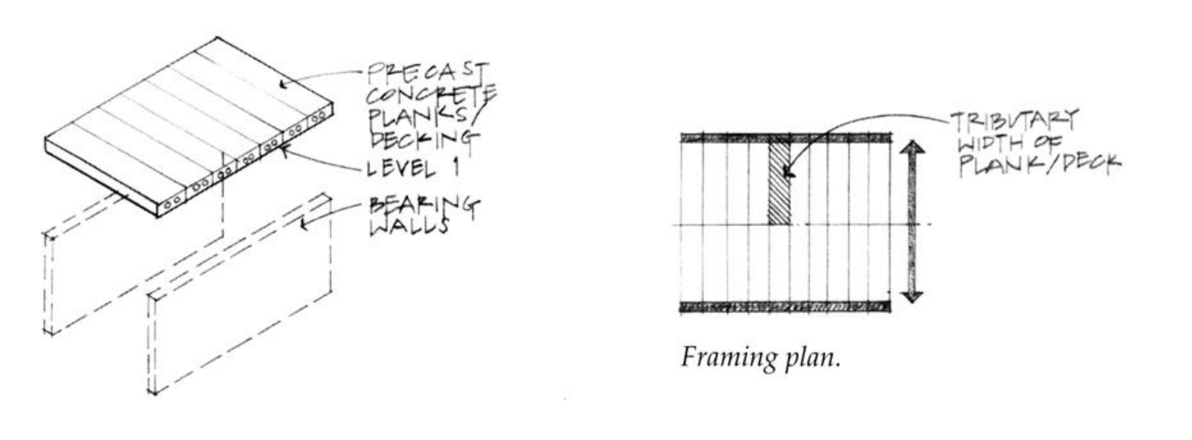
(c) Loads can be reduced on selected beams by introducing intermediate beams.



(d) The span capability of the decking material controls the spacing of the joists, while beam spacing is controlled by the allowable joist span.

Levels

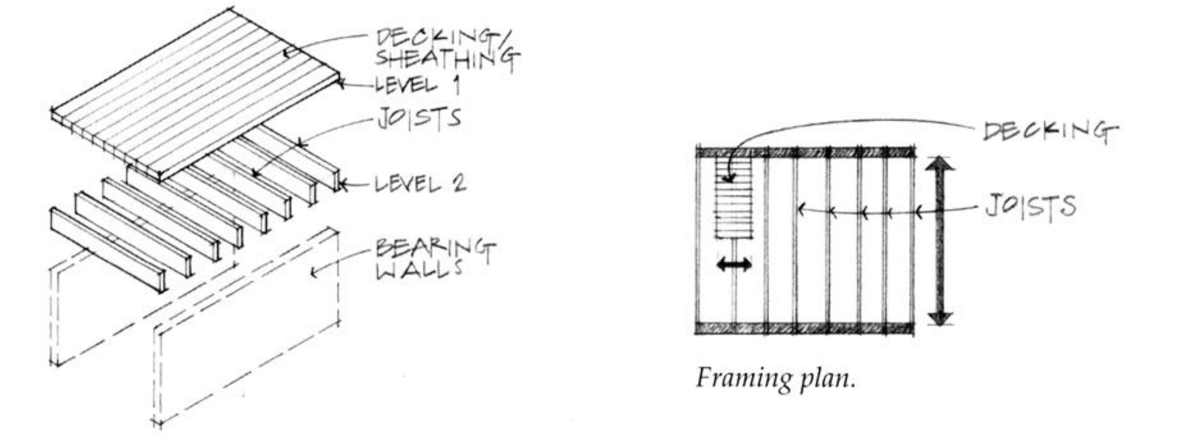
- determine span at top level
- find half way to next element
- *include self weight
- look for "collectors"
- repeat
- one:



Framing plan.

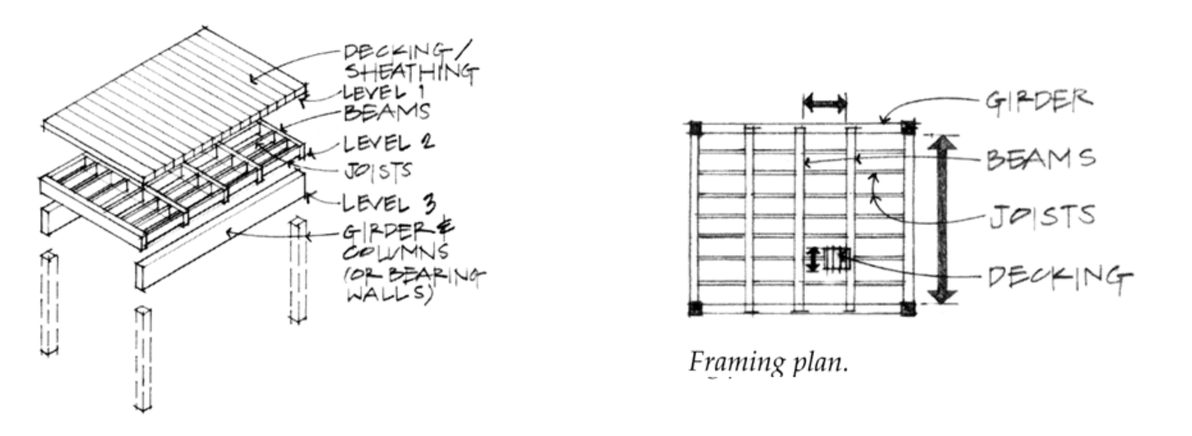
Levels

- two:



Framing plan.

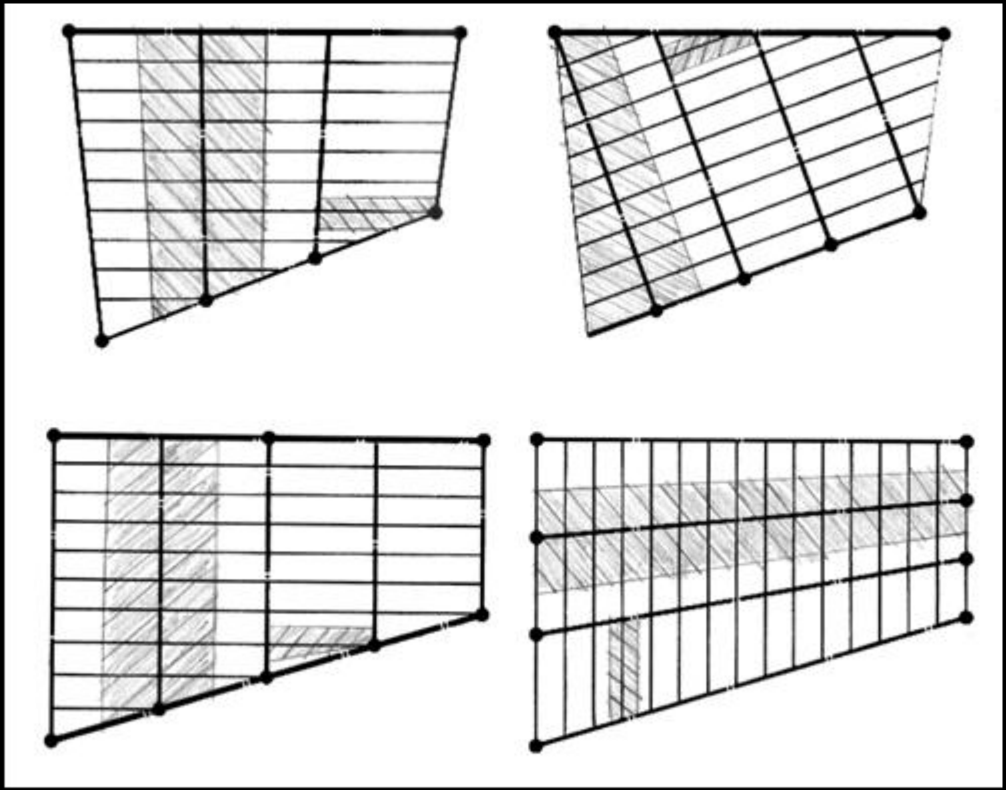
- three:

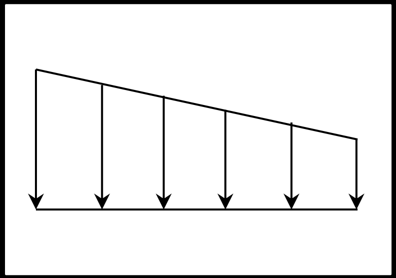


Framing plan.

Irregular Configurations

- *tracing still ½ each side*





Slabs

- edge support

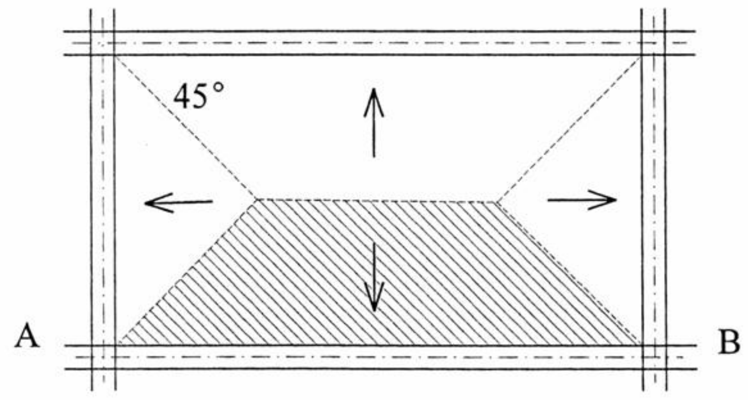


Figure 2-16: Supporting beams' contributing areas for reinforced concrete floor system.

- linear and uniform distribution

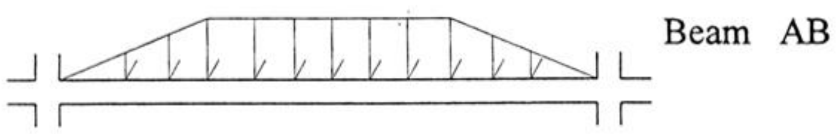


Figure 2-17: Trapezoidal distributed load for Beam AB of Fig. 2-16.

Girders and Transfer

- *openings*
  - *– no load & no half way*
- *girder actions at beam supports*

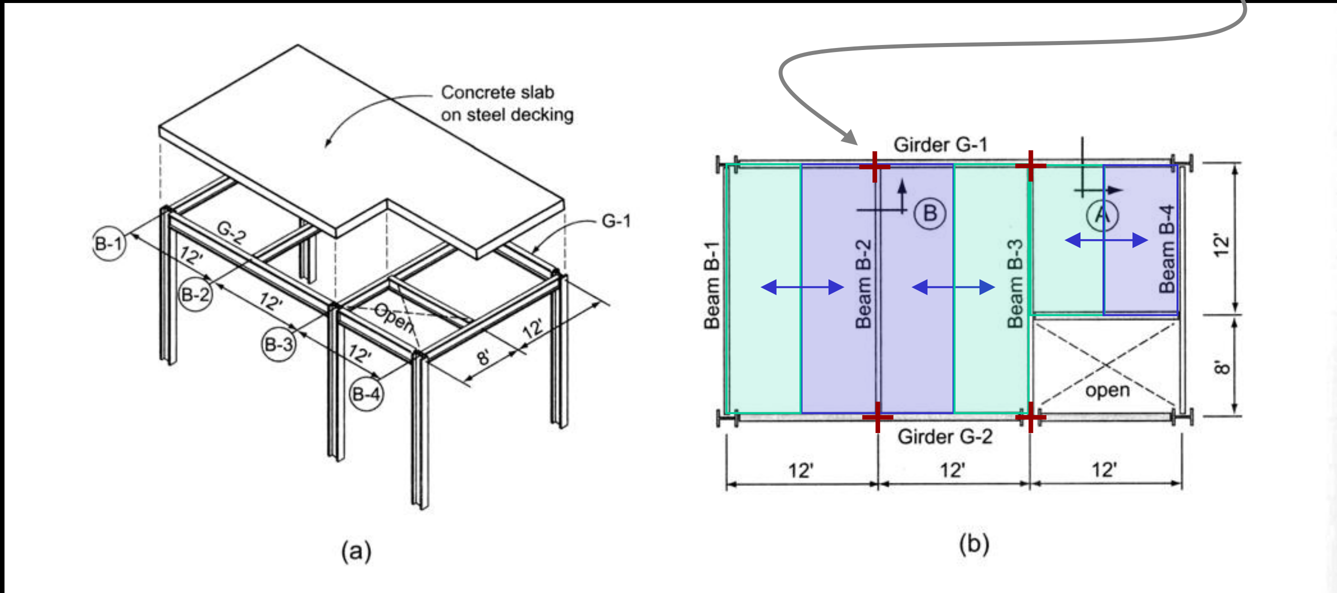
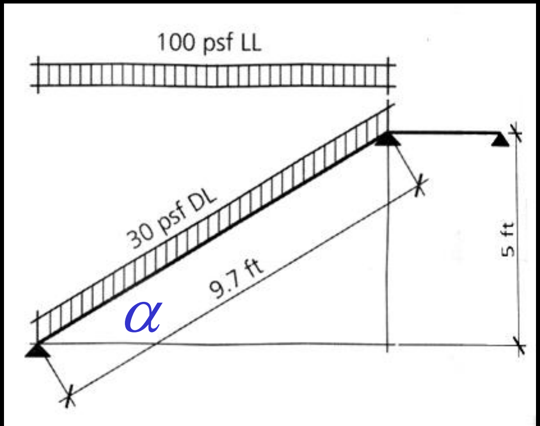


Figure 5.54 (a) Isometric view of partial steel framing arrangement. (b) Partial floor framing—office structure.

Sloped Beams

- *stairs & roofs*
- *projected live load*
- *dead load over length*



- *perpendicular load to beam:*

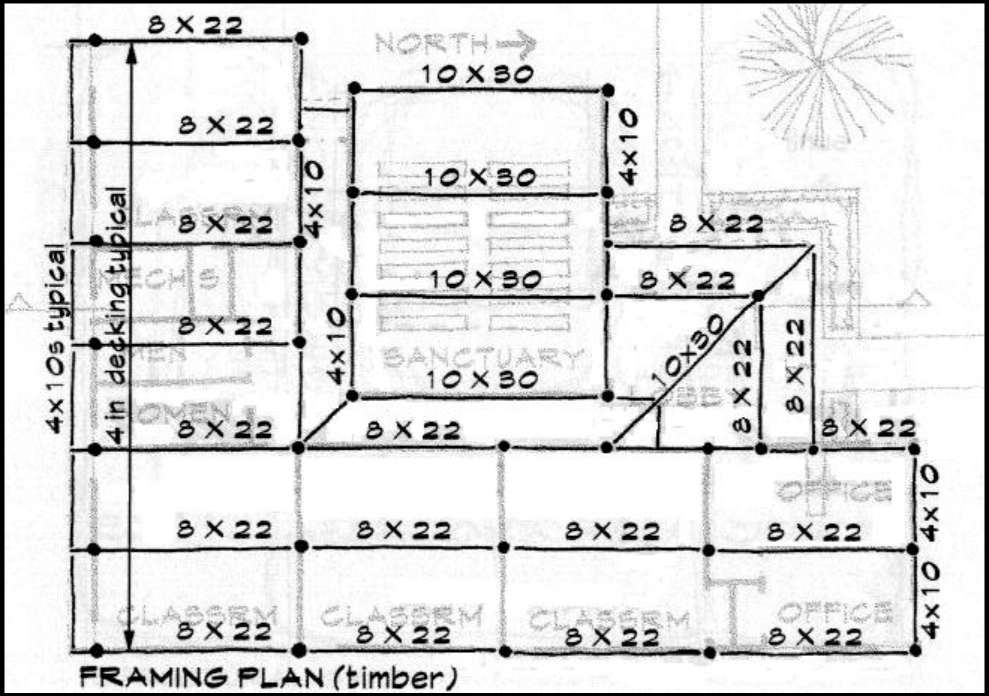
$$w_{\perp} = w \cdot \cos\alpha$$

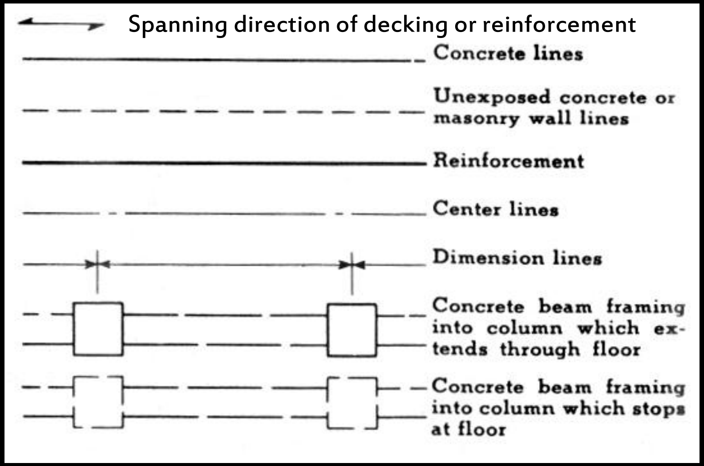
- *equivalent distributed load:*

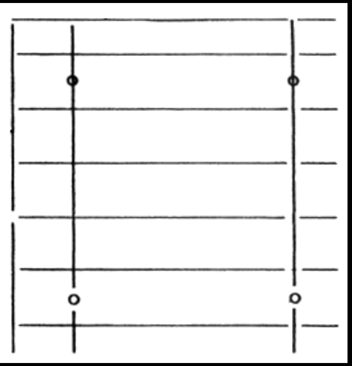
$$w_{adj.} = \frac{w}{\cos\alpha}$$

Framing Diagrams

- *beam lines and "dots"*
- *breaks & ends*

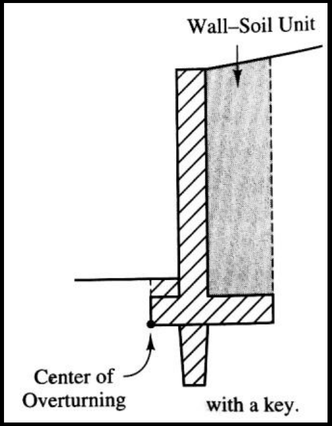


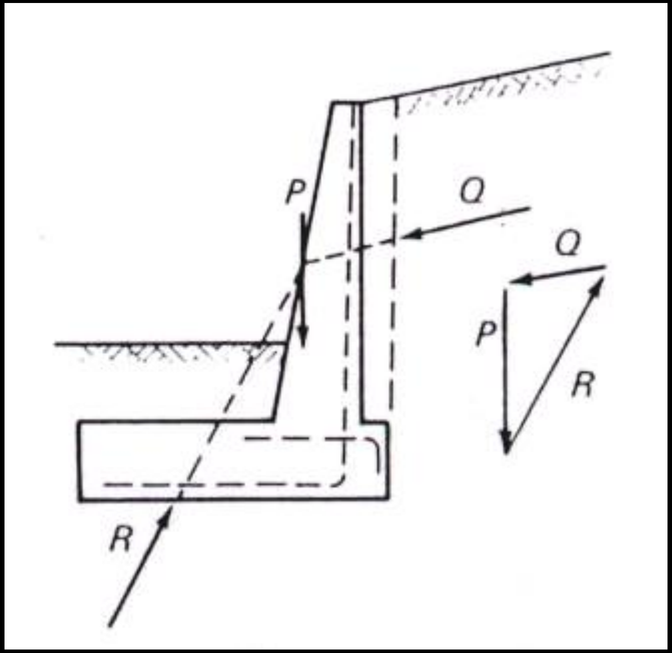




Retaining Walls

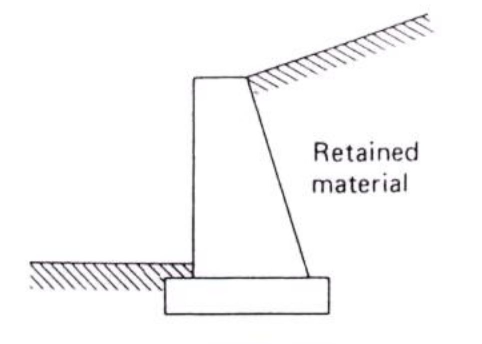
- *purpose*
  - *retain soil or other material*
- *basic parts*
  - *wall & base*
  - *additional parts*
    - *counterfort*
    - *buttress*
    - *key*





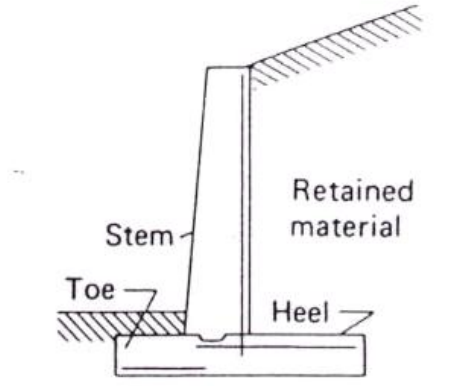
Retaining Wall Types

- *"gravity" wall*
  - *usually unreinforced*
  - *economical & simple*



(a) Gravity wall

- *cantilever retaining wall*
  - *common*



(b) Cantilever retaining wall

Retaining Wall Loads

- *gravity*

  $W = \gamma \times V$

- *fluid pressure*

  $p = \omega' \times h$

  $P = ½\, p\, h$ *at h/3*

- *friction*

  $F = \mu \times N$

- *soil bearing pressure, q*

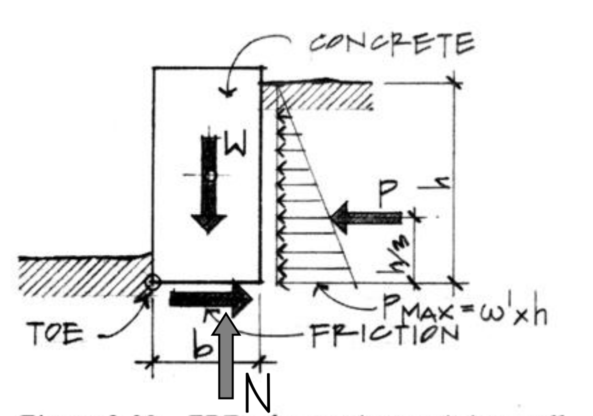


Figure 3.80 FBD of a gravity retaining wall.

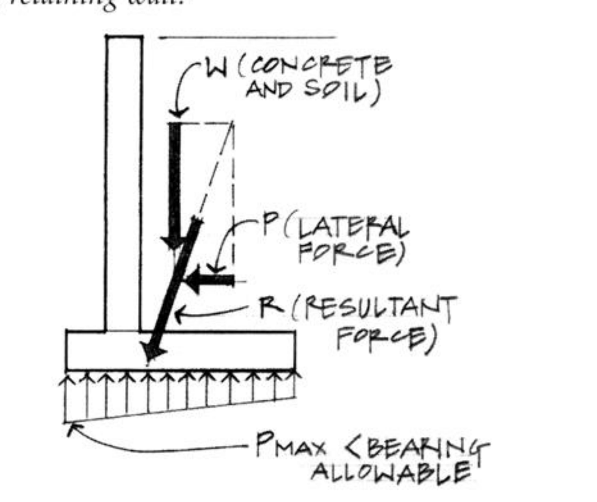
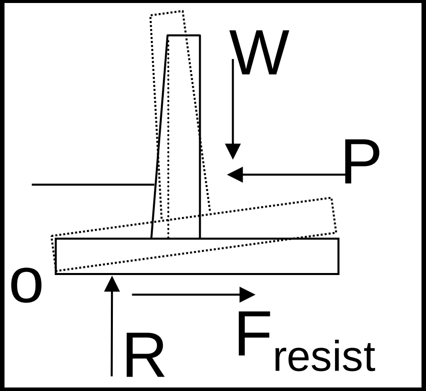


Figure 3.81 Bearing pressure under the wall footing.

Retaining Wall Equilibrium

- sliding - overcome friction?
- overturning at toe (o) - overcome mass?



$$SF = \frac{M_{resist}}{M_{overturning}} \geq 1.5 - 2$$

$$SF = \frac{F_{horizontal-resist}}{F_{sliding}} \geq 1.25 - 2$$

Pressure Distribution

- *want resultant of load from pressure inside the middle third of base (kern)*
- *triangular stress block with p_{max}*
- *x = 1/3 x width of stress*
- *equivalent force location:*

$$W \cdot x = \frac{p_{max} 3x}{2} \cdot \frac{x}{3}$$

$$p_{max} = \frac{2W}{3x} = \frac{2W}{a}$$ *when a is fully stressed*

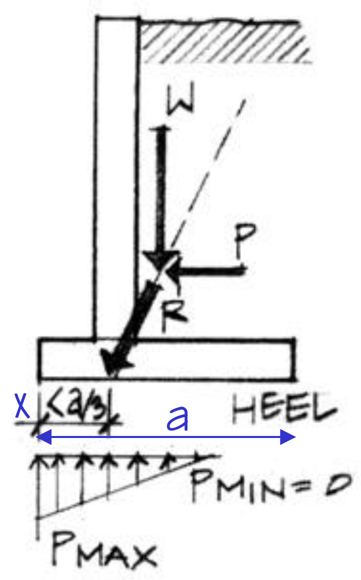


Figure 3.88 Tension possible at the heel.

Wind Pressure

- *distributed load*
- *"collected" into V*
- *lateral loads must be resisted*

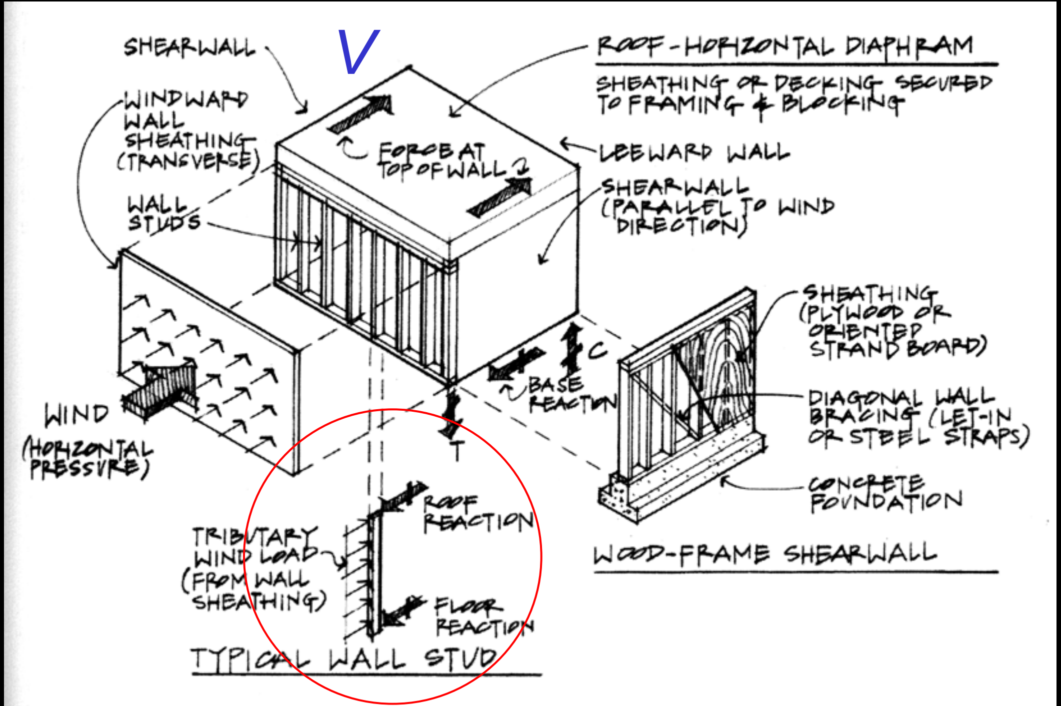


Figure 4.48 Exploded view of a light-framed wood building showing the various lateral resisting components.

Bracing Configurations

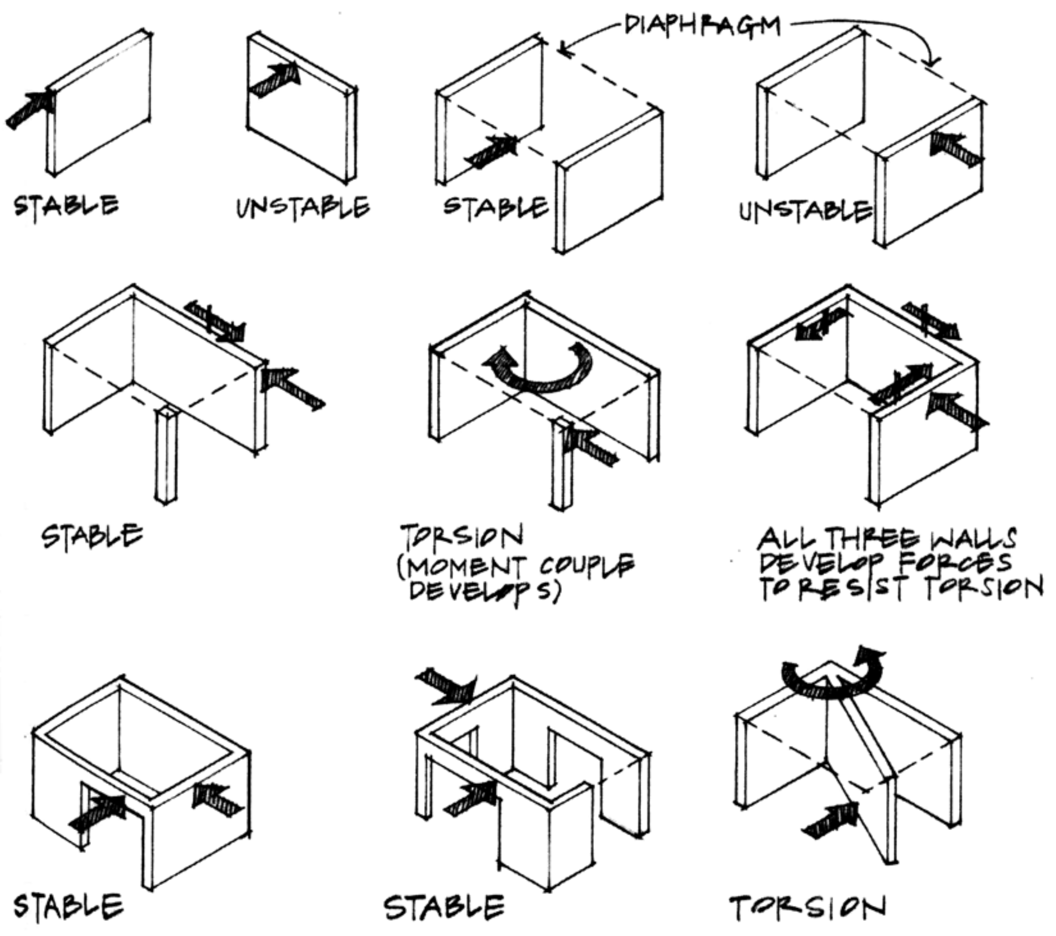


Figure 4.54 *Various shearwall arrangements—some stable, others unstable.*